PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Irrigation As A Management Tool For Stream Temperature

BPA project number: 20133
Contract renewal date (mm/yyyy): ☒ **Multiple actions?**

Business name of agency, institution or organization requesting funding
Department of Rangeland Resources, Oregon State University

Business acronym (if appropriate) OSU

Proposal contact person or principal investigator:

Name	John Buckhouse
Mailing Address	Dept. of Rangeland resources, OSU
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NPPC Program Measure Number(s) which this project addresses

FWS/NMFS Biological Opinion Number(s) which this project addresses

Other planning document references

Short description
Cooling water by moving it toward stream beneath the ground. Subterranean irritation will be used to put water in contact with subsoil

Target species
Salmonoids

Section 2. Sorting and evaluation

Subbasin
Grande Ronde

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories

☒ Anadromous fish ☒ Resident fish ☐ Wildlife	☒ Multi-year (milestone-based evaluation) ☒ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☐ Research & monitoring ☒ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
	Oregon State Legislature mandated water temperature study	Expands geographical region

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1998	Understood groundwater/temp. relationship on Silvies River	Yes

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	qantify subsurface return flow	a	stream flow measurement
2	quantify impact of irrigation on ground water table	b	soil water access tubes
3	quantify length of effuent ground water pattern	c	weekly measurements
4	quantify impact of surrounding vegetation	d	vegetation survey

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	5/2000	12/2001	change in water quantity		25.00%
2	5/2000	12/2001	change in water table		25.00%
3	5/2000	12/2001	change in ground water status		25.00%
4	5/2000	12/2001	quantification of vegetation		25.00%
				Total	100.00%

Schedule constraints

Completion date

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel		%31	25,400
Fringe benefits		%5	4,282
Supplies, materials, non-expendable property		%6	4,500
Operations & maintenance		%8	6,800
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	
NEPA costs		%0	
Construction-related support		%0	
PIT tags	# of tags:	%0	
Travel		%13	10,860
Indirect costs		%27	22,288
Subcontractor		%0	
Other	Publications + Tuition (not included in IC)	%9	7,314
TOTAL BPA FY2000 BUDGET REQUEST			$81,444

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		%0	
		%0	
		%0	
		%0	
Total project cost (including BPA portion)			$ 0

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$75,654			

Section 6. References

Watershed?	Reference
☐	Buckhouse, J.C. 1996. Controlling season, intensity and frequency of grazing. pp. 47-59 IN: George, M.R. (ed.) Livestock Management in Grazed Watersheds: A review of practices that protect water quality. UCD Pub. 3381. Univ. of Calif., Davis, CA.
☐	Buckhouse, J.C. 1996. Riparian zones - a focus for watersheds. IN: Governor's Watershed Enhancement Board (GWEB). "Who Will Catch the Rain?" Conf. Proc., Seaside, OR. Nov. 14-15, 1996.
☐	Buckhouse, J.C. 1996. Watershed assessment: Linking assessment to monitoring; the importance of feedback. IN: Governor's Watershed Enhancement Board (GWEB). "Who Will Catch the Rain?" Conf. Proc., Seaside, OR. Nov. 14-15, 1996.
☐	Buckhouse, J.C., T.K. Stringham and W.C. Krueger. 1996. Stream temperature amelioration through subsurface (interflow) delivery of irrigation water. IN: Proc. 9th Annual James O. Vomocil Water Quality Conf., Oregon State Univ., Corvallis, OR. 3 p.
☐	Buckhouse, J.C., T.K. Stringham, W.C. Krueger and G. Delaney. 1997. Stream temperatures as related to subsurface delivered water. Riparian Ecology, Use and Management: A Symposium. Oregon State Univ., Corvallis, OR. May 27, 1997.
☐	Krueger, W.C. l996. Riparian restoration and data interpretation. IN: Proc. Riparian Restoration and Monitoring Workshop, LaGrande, OR. April 30-May 3, 1996.
☐	Krueger, W.C. 1996. Managing ungulates to allow recovery of riparian vegetation. pp. 160-166 IN: Sustaining Rangeland Ecosystems Symp., Oregon State Univ. Ext. Serv. Spec. Rep. 953. Corvallis, OR.
☐	Krueger, W.C. 1996. Developing an effective grazing strategy for riparian vegetation. pp. 15-23 IN: George, M.R. (ed.) Livestock Management in Grazed Watersheds: A review of practices that protect water quality. UCD Pub. 3381. Univ. of Calif., Davis,
☐	Krueger, W.C. 1997. Riparian restoration and data interpretation. IN: Riparian Ecology and Management Workshop Proceedings. Dept. of Rangeland Resources, Oregon State Univ., Corvallis, OR. 7 p.
☐	Larson, R., W. Krueger, M. Barrington, J. Buckhouse, M. George and D. Johnson. 1996. Livestock influences on riparian zones and fish habitat. A database bibliogoraphy. Oregon Agric. Exp. Sta. EM 8660. Oregon State Univ., Corvallis, OR.
☐	Stringham, T.K. and F.W. Obermiller. 1993. The structure of a resource based economy: Grant County Oregon. A Final Report to the Grant County Court on the Results of the 1992 Input-Output Surveys. Oregon State Univ. Ext. Serv.
☐	Stringham, T.K., J.C. Buckhouse and W.C. Krueger. 1996. Stream temperature as related to subterranean irrigation. pp. 11-18 IN: Rangeland Science Series Report #3, Dept. of Rangeland Resources, Oregon State Univ., Corvallis, OR.
☐	Stringham, T.K., J.C. Buckhouse and W.C. Krueger. 1997. Understanding the thermal regime of a rangeland stream: A case study. Riparian and Watershed Management in the Interior Northwest Symp., LaGrande, OR.
☐	Stringham, T.K. 1998. Meadow ecology and hydrology. pp. 20-28 IN: Rangeland Science Series Report #4, Dept. of Rangeland Resources, Oregon State Univ., Corvallis, OR.
☐	Stringham, T.K., J.C. Buckhouse and W.C. Krueger. 1998. Stream temperatures as related to subsurface water flows originating from irrigation practices. J. Range Manage. 51:88-90.

PART II - NARRATIVE

Section 7. Abstract

Objectives/Hypothesis: The long-term objective is to provide aframework for determining the impact of flood and subterranean irrigation practices on stream temperature. (1) To quantify the amount of subsurface return flow required to depress daily maximum stream temperatures 1 F. (2) To quantify the impact of flood and/or subterranean irrigation on water table gradient during the summer months. (3) To quantify the length of irrigation season required to maintain an effluent water table pattern through August. (4) To quantify the impact of irrigation practices on plant community composition and forage production.
Approach: Plant communities will be mapped and sampled for species composition and forage production at peak standing crop of dominant graminoid. Soil profiles within the respective plant communities will be described. Access wells for monitoring depth to water table will be installed within each plant community. Irrigation treatments will be established to evaluate the impact on stream temperature, groundwater gradient and plant community composition. Stream discharge and amount of stream water diverted for irrigation will be measured from June through September. Temperature of the stream within the irrigated meadow will be compared to upstream non-irrigated control sites.
Expected Results: Increased understanding of the effects of flood and subterranean irrigation practices on the water quality parameter of stream temperature and improvement of irrigation methods to achieve landowner and societal water quality objectives. Increased understanding of the relationship between plant community composition/forage production and depth to water table and/or soil moisture during the growing season. Increased understanding of the effluent and influent water table gradient patterns for semi-arid streams. Peer reviewed and popular press articles will be prepared, workshops held, and other presentations made throughout the state and at national meetings.
Improvements in Management: Irrigation practices have been implicated as a source of water quality degradation on streams throughout Oregon and the West. This project will improve the ability of managers to predict the ecological consequences of two types of irrigation practices common in the intermountain West.

Supplemental Keywords: flood/subterranean irrigation, stream temperature, ecological effects, fisheries, management, Oregon.

Section 8. Project description

a. Technical and/or scientific background

Water temperature has been demonstrated to be an important variable restricting the survival of desirable cold water fisheries in the West. Elevated stream temperatures contribute to declines in spawning success and greater incidence of fish disease (Theurer et. al. 1985). The net impact of elevated water temperature is a decreased population of desirable fish species and under extreme conditions the disappearance of certain salmonid species. The Oregon Department of Environmental Quality (1998) most recent water quality standards categorized a number of Oregon streams as water quality limited on the basis of temperature. The inclusion of water temperature as a standard for water quality by regulatory agencies has initiated the need for a better understanding of the possible influence of management practices on the environmental factors determining stream temperature.

b. Rationale and significance to Regional Programs

There is growing concern that agricultural irrigation practices which divert stream water have a negative impact on water quality by decreasing stream flow and increasing water temperature. The proposed research will supplement an ongoing stream temperature/irrigation study. This research will study the response of plant communities, forage production, water table gradients and stream temperature to specified irrigation practices. Combining the results of this research with ongoing projects will significantly improve understanding of the spatial and temporal impacts of flood/subterranean irrigation practices on the water quality variable of stream temperature.

Designation of water temperature in streams as a water
quality standard has resulted in large numbers of stream reaches being put on the Oregon state list of water quality limited streams (the 303(d) list of the Clean Water Act). It is our expectation that this project will further our understanding of the relationship between subsurface return flow and stream temperature. In addition, this project will provide knowledge that will allow land managers in some areas of the West to positively impact stream temperature through irrigation. Furthering our understanding of the relationship between plant communities and water table depth and/or soil moisture will allow managers to predict changes in species composition and forage production caused by irrigation manipulations or changes in creek morphology. One of the major benefits of this project will be to provide land managers with a tool that they can control for the benefit of both the forage resource and the aquatic environment.

c. Relationships to other projects

Although there are a number of interrelated factors which determine the thermal signatures of streams the most important hydrologic variables have been identified as the source of the water, the flow or discharge, and the relative contribution of groundwater (Ward 1985). Groundwater provides baseflow and moderates the effect of seasonal air temperature fluctuations. Meisner (1990) found groundwater discharge maintained coldwater habitat in headwater streams while shade performed an accessory role by reducing insolation. Stream segments that received a proportionately greater contribution of groundwater at low flow have been found to exhibit depressed daily maximum temperatures (Mosley 1983; McRae and Edwards 1994). Subterranean irrigation, where water is diverted from the stream, carried by a ditch along the flood plain edge and allowed to return to the stream via subsurface interflow, may mimic the cooling effect noted with groundwater. Two years of data from a case study in Grant County, Oregon indicates that return flow from irrigation reduced daily maximum stream temperatures by 1 to 3°C (Stringham 1998). Expanded research at additional sites and with varying irrigation methodologies is necessary to establish principles for management of stream temperature through augmentation of interflow by irrigation practices.

Literature Cited

McRae, G. and C.J. Edwards. 1994. Thermal characteristics of Wisconsin headwater streams occupied by beaver: Implications for brook trout habitat> Trans. of the Amer. Fisheries Society 123:641-656.

Meisner, J.D. 1990. Effect of climatic warming on the southern margins of the native range of brook trout, *Salvelinus fontinalis.* Canadian J. of Fisheries and Aquatic Science 47:1065-1070.

Mosley, M.P. 1983. Variability of water temperatures in the braided Ashley and Rakaia Rivers. new Zealand J. Marine Freshwater Res. 17:331-342.

Oregon Dept. of Environmental Quality. 1998. Oregon Listing Criteria. 28 p.

Stringham, T.K. 1998. Meadow ecology and hydrology. pp. 20-28 IN: Rangeland Science Series Report #4, Dept. of Rangeland Resources, Oregon State Univ., Corvallis, OR.

Theurer, F.D., I. Lines and T., Nelson. 1985. Interaction between riparian vegetation, water temperature and salmonid habitat in the Tucannon River. Water Resources Bull. 21:53-64.

d. Project history (for ongoing projects)

e. Proposal objectives

(1) To quantify the amount of subsurface return flow

required to depress daily maximum stream temperatures 1°C.

(2) To quantify the impact of flood and/or subterranean irrigation on water table gradient during the summer months.

(3) To quantify the length of irrigation season required to maintain an effluent water table pattern through August.

(4) To quantify the impact of irrigation practices on plant community composition and forage production.

f. Methods

Objective 1

To quantify the amount of subsurface return flow required to depress daily maximum stream temperatures 1°C.

$H_{o:}$ Subsurface return flow does not depress daily maximum stream temperature in reaches located within the irrigated meadow.

Permanent cross-section stations will be located on the stream above and below the diversion dam, at the center point of the irrigated meadow and the bottom of the irrigated meadow. Discharge measurements will be taken every 3 days during the irrigation season. Differences in discharge between sites located within the irrigated meadow and the site directly below diversion will allow an approximation of return flow. Each cross-section will be instrumented with a combination of air, water, and ground thermistors. Air and water thermistors will be programmed to continuously record temperature on 36 minute intervals. Ground thermistors programmed to record temperature every 3 hours will be placed 70 cm below the ground surface.

Objective 2 & 3

To quantify the impact of flood and/or subterranean irrigation on water table gradient during the summer months.

To quantify the length of irrigation season required to maintain an effluent water table pattern through August.

$H_{o:}$ Flood and/or subterranean irrigation does not impact depth to water table or water table gradient.

Water table access wells constructed of 3/4" PVC pipe will be installed. Six randomly placed transects of 4 wells each, placed perpendicular to the stream, will be located on each side of the stream in an alternate pattern. The benchmark well will be located within 1 m of the stream channel for each transect. Wells will be surveyed using conventional survey methods to determine elevation change with respect to the benchmark well. Depth to water table will be measured every 3 days from June through September. Water table profiles relative to the creek surface will be calculated.

Objective 4

To quantify the impact of irrigation practices on plant community composition and forage production.

$H_{o:}$ There is no relationship between depth to water table and/or soil moisture and the associated plant community.

Plant community types will be mapped on the basis of dominant graminoid. Water table access wells will be randomly assigned by plant community. Depth to water table and gravimetric soil moisture samples (30 and 45 cm depth) will be taken every 10 days from June through August.

g. Facilities and equipment

The proposed study location is Milk Creek located in Union County, Oregon on the Hall Ranch owned by the Eastern Oregon Agricultural Research Center. Milk Creek is a second order stream and a tributary to Catherine Creek. The stream is considered critical rearing habitat for the Snake River run of spring chinook salmon (*Oncorhynchus tschawytscha*). This particular run of spring chinook was listed as a threatened species in 1992. Approximately 25 years ago, irrigation withdrawal from Milk Creek was terminated, however, the head ditches and diversion dams still exist. The timing and magnitude of irrigation diversion will be under the control of the researcher allowing true experimental manipulation of irrigation regimes.

Hobo temp thermisters have created a technology which has been a boom to water temperature researchers. These data loggers are able to collect 1800 bits of information over any selected time period. By placing the thermisters in the stream, in the irrigation ditches, in soil water access tubes, as well as the atmosphere, we are able to track water temperatures throughout the day, the season, and as it reaches equilibrium with groundwater.

h. Budget

	FY 2000	**FY 2001**	**Total**
Salaries:			
Graduate Research Assistant	13,000	13,520	26,520
J. Buckhouse (.05 FTE)	3,800	3,952	7,752
T. Stringham (.10 FTE)	8,600	8,996	17,596
Total Salaries	25,400	26,468	**51,868**
Employee Benefits:			
GRA	130	135	265
PI	1,254	1,423	2,677
Co-PI	2,898	3,239	6,137
Total Employee Benefits	4,282	4,797	**9,079**
Travel:			
Corvallis-Union	4,000	4,500	8,500
Professional meetings	2,000	2,000	4,000
Summer use vehicle	4,860	4,860	9,720
Total Travel	10,860	11,360	**22,220**
Minor Equipment:			

Software	300	0	300
Laptop computer	2,000	0	2,000
Thermisters and casings	4,500	0	4,500
Total Equipment	6,800	0	**6,800**
Supplies:			
Field supplies	4,500	4,500	9,000
Total Supplies	4,500	4,500	**9,000**
Other:			
Publications	600	850	1,450
Tuition	6,714	7,050	13,764
Total Other	7,314	7,900	15,214
Sub-Total	52,942	48,475	**114,181**
Indirect Costs	28,502	27,179	55,681
Total	81,444	75,654	**157,098**

Budget Justifications:

Laptop computer is to be used on the project to download data loggers and analyze information on-site.

Off-campus Indirect Cost Rate - Field and research station located at Mill Creek, Union County, Oregon.

Section 9. Key personnel

John C. Buckhouse. Professor Watershed Management. .05 FTE devoted to project. OSU professor since 1975. Over 150 publications on watershed management and water quality. Member of Independent, Multidisciplinary Science Team for Oregon Plan (for Salmon Recovery).

B.S. 1966 UC Davis
M.S. 1968 Utah State University
PhD 1974 Utah State University

Stringham, T.K., J.C. Buckhouse and W.C. Krueger. 1998. Stream temperatures as related to subsurface waterflows originating from irrigation practices. J. Range Manage. 51:88-90

Larson, R.E., W.C. Krueger, M.R. George, M.R. Barrington, J.C. Buckhouse and D.E. Johnson. 1998. Livestock influence on riparian zones and fish habitat: Literature classification. J. Range Manage. 51:661-664.

Buckhouse, J.C. 1996. Controlling season, intensity and frequency of grazing. pp. 47-59 IN: George, M.R. (ed.) Livestock Management in Grazed Watersheds: A review of practices that predict water quality. UCD Pub. 3381. Univ. Calif., Davis, CA.

National Research Council. 1994. Rangeland Health: New methods to classify, inventory and monitor rangelands. National Academy Press. Washington, D.C.

Bedell, T.E. and J.C. Buckhouse. 1994. Monitoring primer for rangeland watersheds. U.S. EPA, Region 8, Denver, CO. EPA-908-R-94-001.

William C. Krueger. Professor and Department Head, Dept. of Rangeland Resources. 0.10 FTE devoted to project. OSU professor since 1970. Over 175 publications on rangelands, watersheds, and ecology.

B.S.	1975	St. Mary's University
M.S.	1967	Humboldt State University
PhD	1970	Utah State University

Krueger, W.C. l996. Riparian restoration and data interpretation. IN: Proc. Riparian Restoration and Monitoring Workshop, LaGrande, OR. April 30-May 3, 1996.

Krueger, W.C. 1996. Managing ungulates to allow recovery of riparian vegetation. pp. 160-166 IN: Sustaining Rangeland Ecosystems Symp., Oregon State Univ. Ext. Serv. Spec. Rep. 953. Corvallis, OR.

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Larson, R., W. Krueger, M. Barrington, J. Buckhouse, M. George and D. Johnson. 1996. Livestock influences on riparian zones and fish habitat. A database bibliogoraphy. Oregon Agric. Exp. Sta. EM 8660. Oregon State Univ., Corvallis, OR.

Tamzen K. Stringham. Research Associate, Dept. of Rangeland Resources since 1997. Responsible for water quality data collection and analysis for State Legislature mandated water temperature (GWEB administered) project.

B.S.	1981	Chico State University
M.S.	1983	Oregon State University
PhD	1996	Oregon State University

Stringham, T.K. and F.W. Obermiller. 1993. The structure of a resource based economy: Grant County Oregon. A Final Report to the Grant County Court on the Results of the 1992 Input-Output Surveys. Oregon State Univ. Ext. Serv.

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Section 10. Information/technology transfer

This information will be disseminated through a variety of means: Refereed journal publications, Extension publications, professional meeting abstracts, and as professional invited papers. The personnel involved are active adherents to the concepts that such information needs to be available to other scientists, agency personnel, landowners, and the general public.

Congratulations!